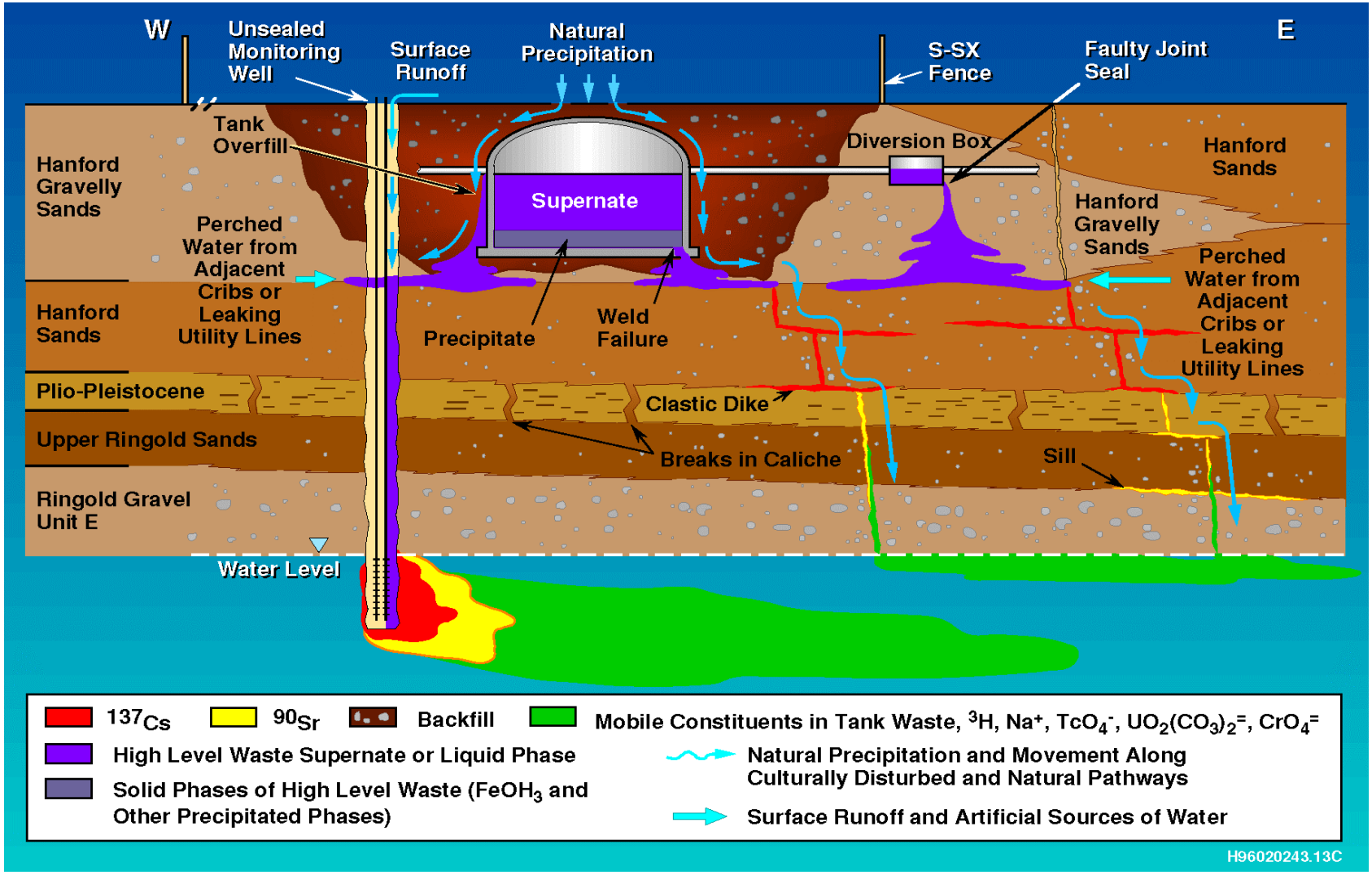
EMSP
Environmental Management Science Program

The Dynamics of Vadose Zone Transport: A Field and Modeling Study Using the Vadose Zone Observatory

C.R. Carrigan, P.I. (EMSP: 70149)
S. Martins, W. Daily, A.Ramirez
Lawrence Livermore National Laboratory

November 6, 2001

What Is The Role Of The Vadose Zone As A Time-Dependent Source Of Contamination To The Watertable?



Some Photos/Illustrations Courtesy PNL & Bechtel

Primary Research Questions

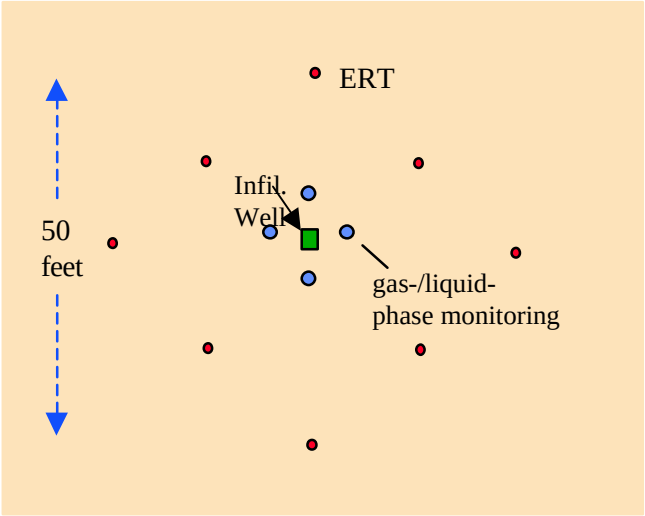
How does infiltrating water move across a heterogeneous vadose zone in general and specifically at Hanford?

How does infiltrating water interact with existing contamination in general and specifically beneath the tanks at Hanford?

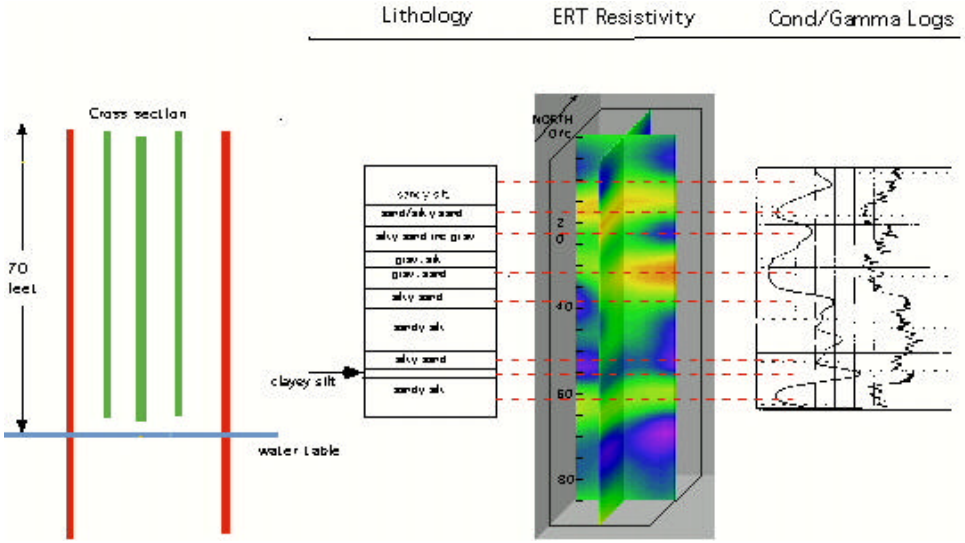
How can subsurface imaging better elucidate vadose zone processes?

Vadose Zone Observatory: Supporting Field & Modeling Studies At Hanford And Other Sites

VZO Monitoring Well Planview

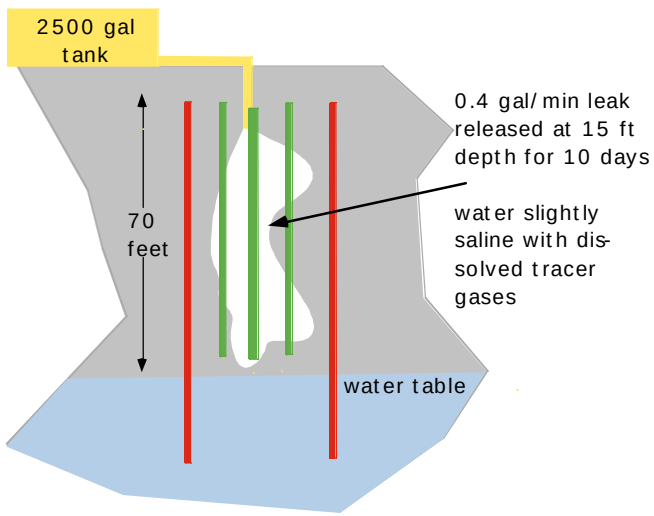


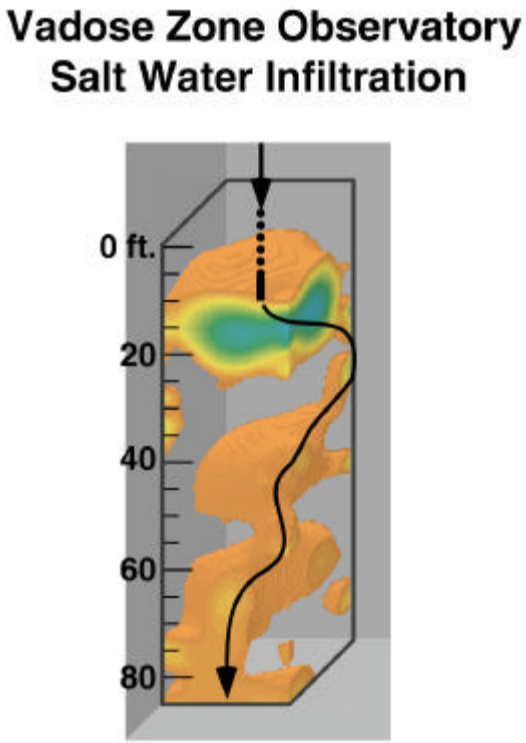
Site Characterized by Geological Logs, ERT and Borehole Logs



EMSP
Environmental Management Science Program

Analog “Leaks”: Monitor Infiltration With Multiple Techniques Improves Understanding Of Techniques & Transport Processes





Infiltration Parameters Monitored

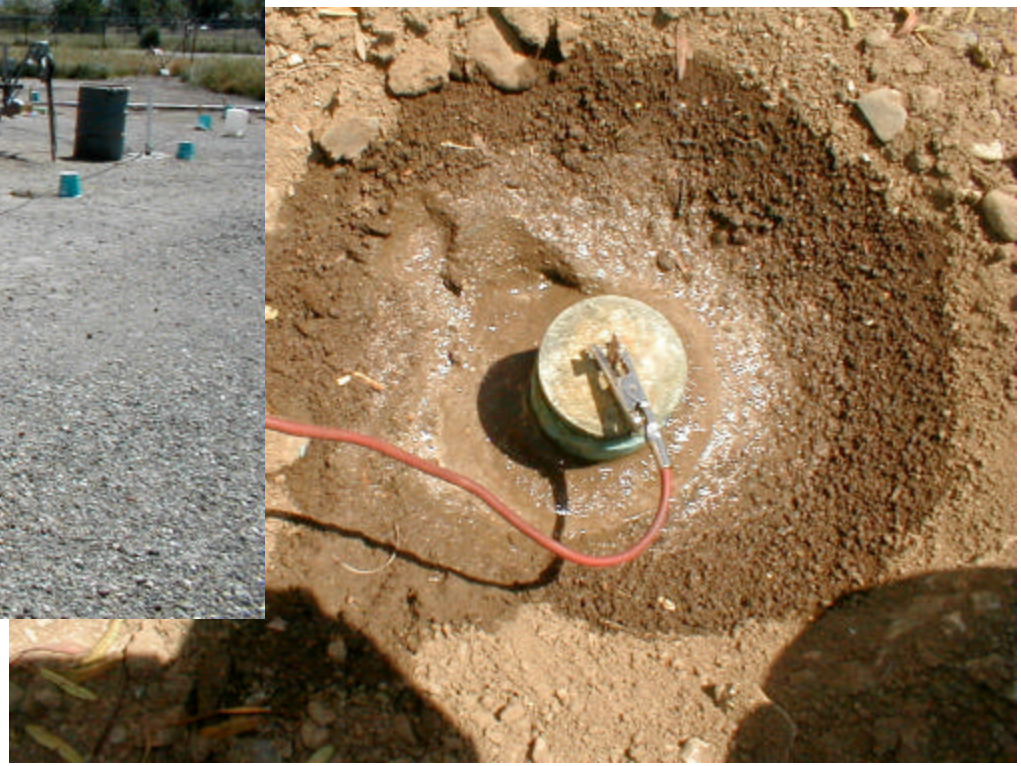
* Liquid phase location versus time (ERT/tracers)
* Gas phase location versus time (noble tracers)
* Gas-phase pressure at various depths
* Liquid phase saturation
* Gas & liquid phase sampling

Some Significant Things We Have Learned

1. Low permeability soils don't necessarily mean low bulk transmissivity for downward transport
2. We have <u>not</u> been able to induce flow into uncased wells during leakage events
3. However, there is evidence for fast-path transport downward at the VZO site
4. ERT/EIT is presently limited in distinguishing between movement of native groundwater and contaminants
5. ERT observations and groundwater tracer sampling have always agreed on arrival of contaminants at the water table
6. Both VZO observations and modeling support the view that the soil matrix functions as storage for contaminants for long-term metering to the water table while high permeability paths explain observed prompt but small-volume water table contamination
7. Barometric fluctuation monitoring at site infers bulk permeability that is comparable to values obtained from actual infiltration experiments
8. EMIT borehole tool turned in promising performance while GPR did not
9. SP monitoring using ERT arrays consistent with ERT results regarding plume formation

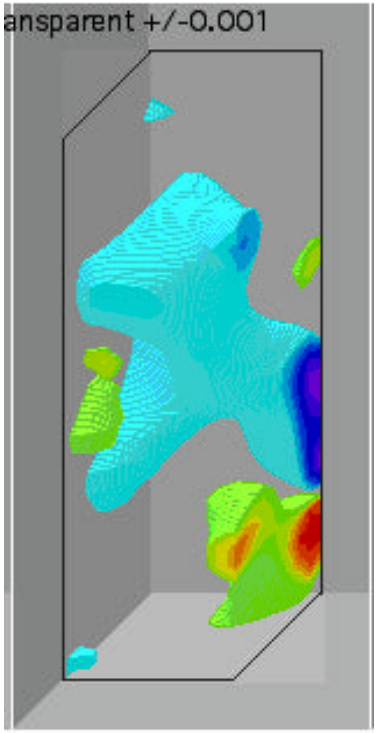
EMSP
Environmental Management Science Program

Plume Imaging: Passive Potentials Compared To ERT

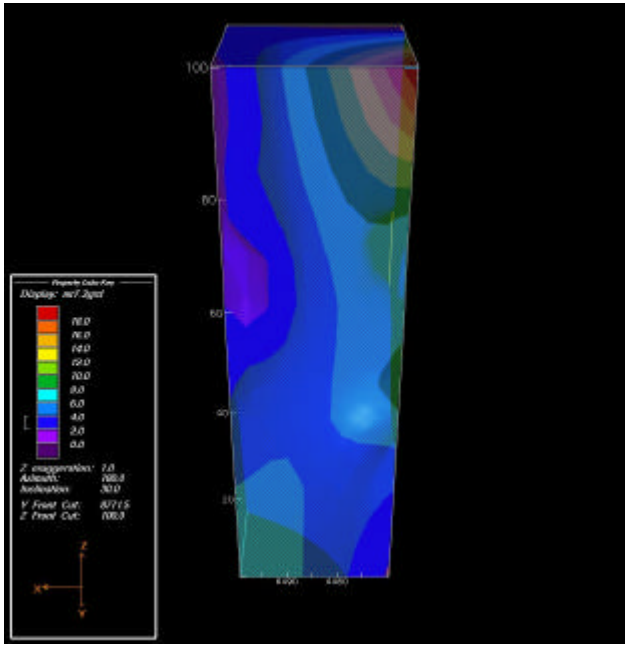


EMSP
Environmental Management Science Program

Resistivity & Potential Near End Of Infiltration (Using Well Electrodes)



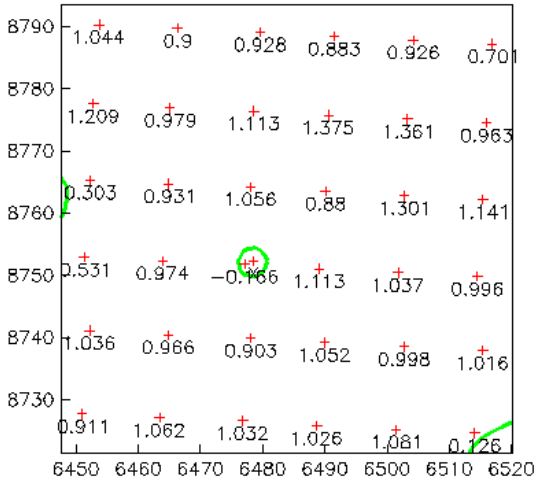
Resistivity Structure



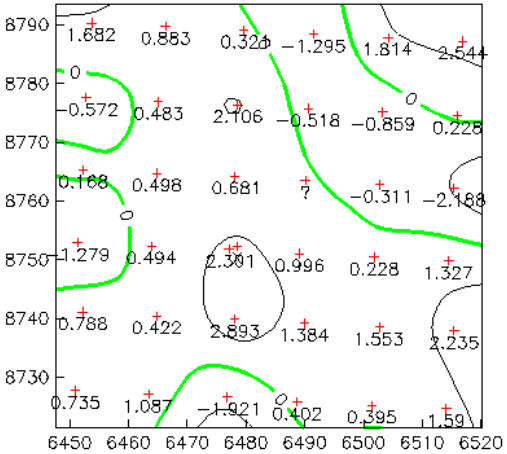
Passive Potential

EMSP
Environmental Management Science Program

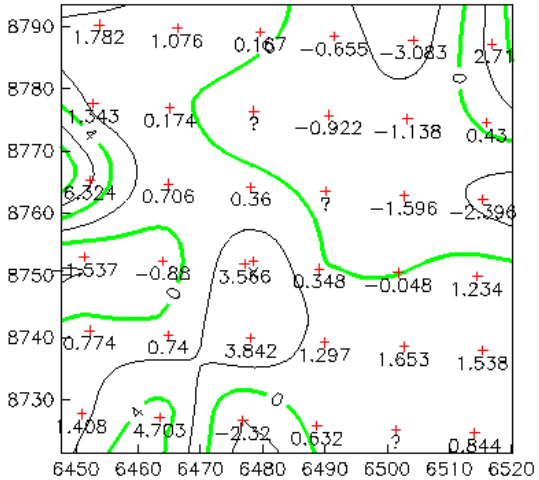
Surface Potentials As A Function Of Time



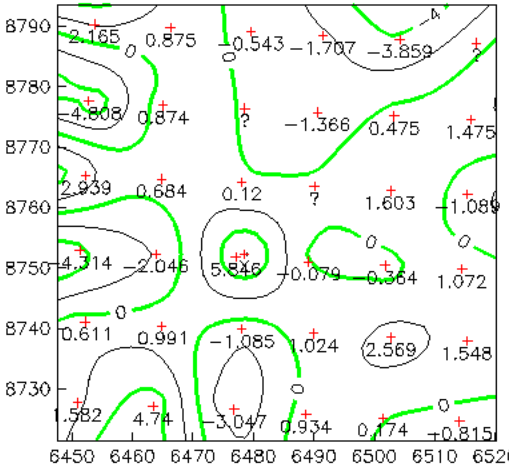
1 hr



24 hr



47 hr



79 hr

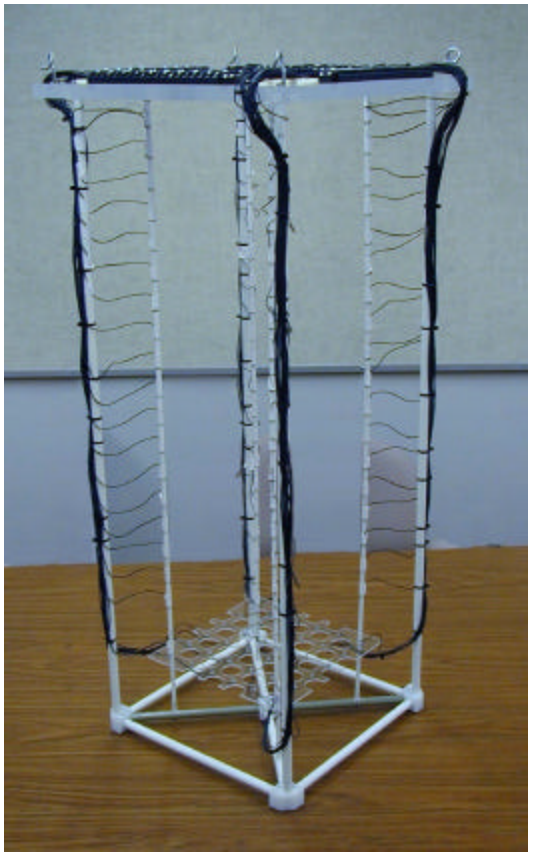
EMSP
Environmental Management Science Program

Independent Estimates of Vadose Zone Permeability (With Jim Lombard At Geosystems Analysis)

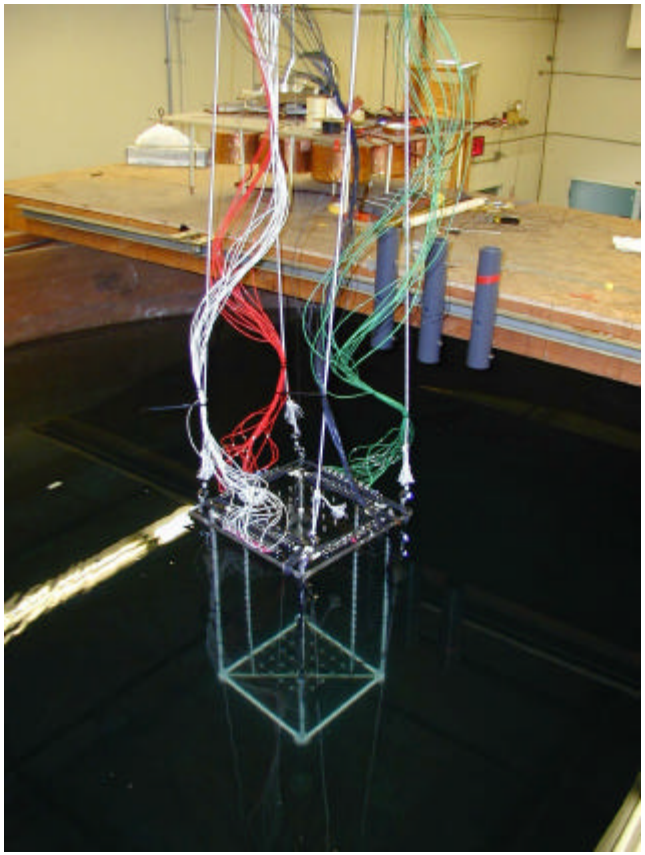
Barometric based estimates in excellent agreement with ERT/modeling based estimates

Depth Interval (m bgs)	Permeability (Darcy)
0.0 -2.4	16.
2.4 - 5.0	2.8
5.0 - 20.0	15.

Lab Studies of ERT Imaging Necessary To Elucidate Relationships Between Images & Flows



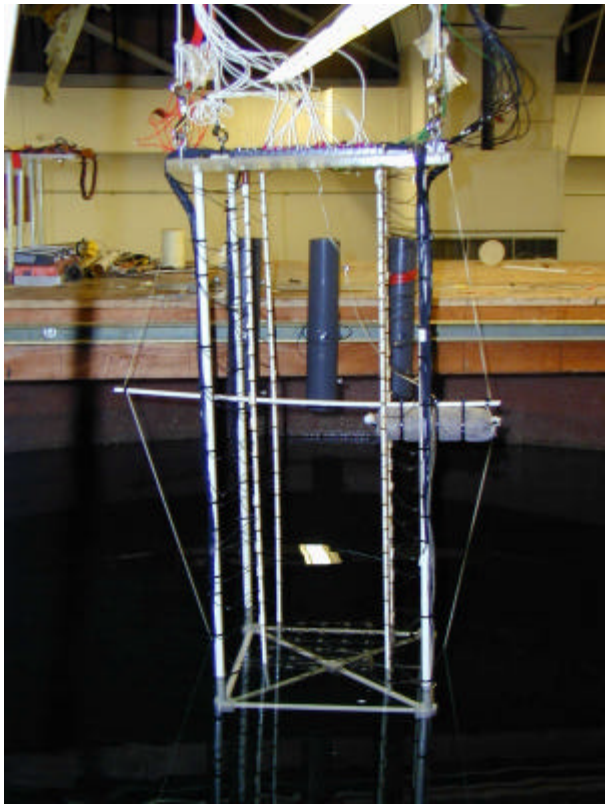
VZO ERT array model

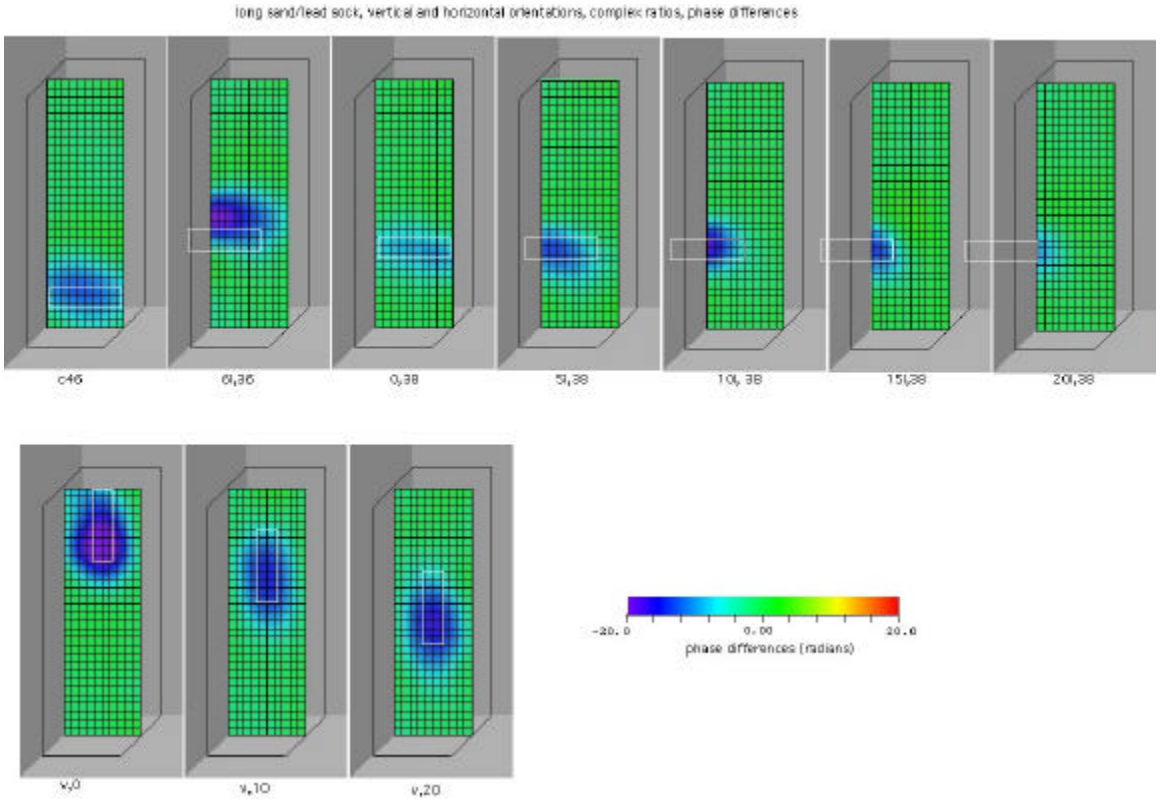


Lowered into “infinite” tank

EMSP
Environmental Management Science Program

Imaging Conductivity Anomaly At Different Locations In VZO Electrode Array Model





Conductive “sock” target positioned in array

ERT Images of target “sock” at different locations in array with indication of actual Target locations

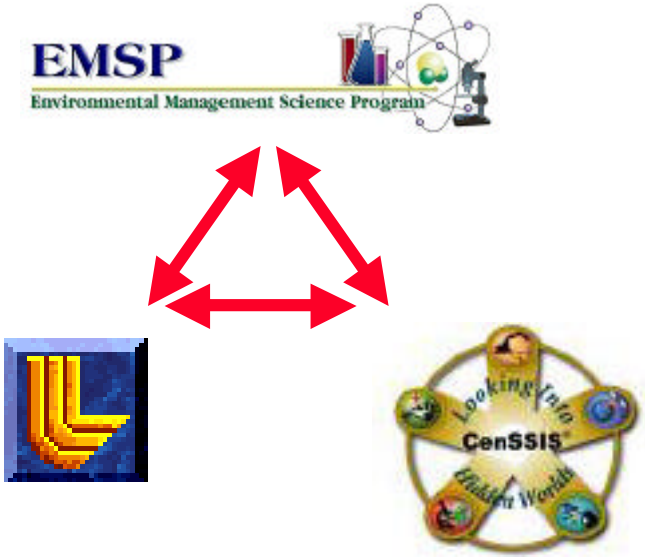
EMSP
Environmental Management Science Program

What Lessons Have We Learned To Date?

- 1-D layered transport models cannot predict tracer arrivals at w.t.
- 3-D geostatistical models capture bulk tracer arrivals at w.t.
- 3-D geostatistical models still miss apparent “fast-path” behavior
- Heterogeneity can severely affect tracer arrivals at nearby wells
- Don’t fully understand relationship of ERT & models of transport
- Need to use tomographic data more effectively to improve models

Where Do We Go From Here?

- Use models as framework to understand field observations
- Develop methods to “condition” simulations with field observations
- Leverage effort with OBES/NSF CenSSIS collaborations



Center for Subsurface Sensing & Imaging Systems (NSF)

An R & D Transition Strategy

- Link to projects where response of vadose zone to infiltration is an issue that site managers are genuinely pursuing.
- Hold short, informal workshops on contaminant transport and imaging issues for site people.
- Provide methodologies to sites for using field experiments and observations to enhance predictive modeling of contaminant transport.
- Provide predictive modeling support for field studies